ART. V.—*Geology of the Lower Moorabool.*

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(Plates I. and II.)

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The valley of the Moorabool River from its confluence with the Barwon, at Fyansford, to a short distance above Maude, displays a series of sections extending over some twenty miles in length which clearly illustrate the diversified character and the relations of our marine tertiary beds and the deposits associated with them. We have previously described the series as shown at the southern end of the valley, and pointed out that the Miocene beds of the old survey really underlay their Oligocene (1). At a subsequent date we dealt with the tertiaries in the neighbourhood of Maude (2), and showed that the same sequence held, while the close relationship between the marine beds underlying the Older Volcanic rock and those of Spring Creek enabled us to indicate the sequence of the tertiaries generally. Since the publication of these papers we have examined the valley for some miles to the north of Maude, and also the undescribed and only partly mapped portion between Russell's Bridge (The Clyde) and the railway viaduct near the Moorabool Station. Our inspection of the beds shows that the general south-westerly dip, which we previously indicated as existing in the southern part of the valley, holds as far to the northward as Maude, near to which place the marine conditions give place to freshwater ones.

Beginning at the northern end of the area under consideration, we find that about half a mile above the confluence of Woolshed Gully, or about a mile and a half below the junction of

Coole Barghurk Creek, there is a thick mass of volcanic rock overlying the Ordovician. Its thickness we estimated at about 150 feet. The lower part of the igneous rock, as seen in several sections, is very much decomposed, while that near the surface is columnar and sound. It would appear from this that there is some difference in the age of the upper and lower parts.

On consideration we are inclined to think that the Newer Volcanic rock here rests on the Older Volcanic without the presence of any intervening beds, and it is not till we have gone some three miles to the southward, in the neighbourhood of the Maude Bridge, that we are able, owing to the occurrence of an intercalated marine limestone, to separate the two with certainty.

Under the volcanic rock occurs a deposit of sand and gravel, which can be traced down stream till it is clearly seen to pass in its upper part into the Lower Maude marine beds, the representatives, as we have previously stated, of the Lower Spring Creek series. To the northward these gravels, which are in places represented by quartzites, have been shown by Selwyn and the officers of his staff to underlie auriferous gravels, and where examined by them, to be not gold-bearing (5). From the data thus obtained, as well as from observations on some of the older gravels elsewhere, which were also non-auriferous, Selywn arrived at the conclusion that gold was not to be found in Miocene gravels. In the same report (5, p. 24) he says, "No beds whatever containing marine fauna are known in Victoria overlying alluvial or drift gold deposits." Since then, however, such beds have been found near Stawell under marine deposits of apparently Eocene age. Selywn's explanation of what he held to be the non-auriferous character of the Miocene gravels is that the age of the auriferous quartz reefs was Post-Miocene, the non-auriferous ones being of greater age. Now that we know of the existence of detrital auriferous deposits of greater age, another explanation of the absence of gold from the gravels north of Maude must be sought, and the true one appears obvious. The gold in our Ordovician is practically confined to beds of certain ages, and we thus find the north and south lines of auriferous country separated by barren belts. One of us has shown that such a barren belt is indicated at Castlemaine by the presence of graptolites belonging to what he has called the *Loganograptus* zone (6, p. 76). Graptolites of a slightly higher horizon occur in Sutherland's Creek, and a few that may be of the same age at the localities shown on Quarter-sheet 19, S.W., in the Moorabool Valley. The reason, then, for the absence of gold in the gravels appears to be that they have been derived from a barren belt of Ordovician, and not that the character of the quartz veins depends on the age of their formation.

At the locality marked W.T.M.8. on the Quarter-sheet the summit of the Ordovician is about eighty feet above the level of the river, which flows through a rugged gorge. Half a mile below this the gravels pass up into marine beds.

These consist in the main of polyzoal limestones, and are strongly current bedded, containing quartz grains the size of a pea, as well as numerous flakes of slate. In places the limestone is crowded with vast quantities of the peculiar little echinoderm, *Fibularia*. These beds, which are a part of the "Lower Maude Series," are probably about the level of Lethbridge Station, which is 547 feet above sea level, and are the most northerly exposure of the marine beds. From here the surface of the Ordovician drops rapidly as we go south, and in about two miles it has disappeared beneath the level of the bottom of the valley. The Lower Maude series of marine beds, which have now almost entirely displaced the gravels, disappear in the same way a little further down stream, as shown on the Quarter-sheet. The section just above this is described in a previous paper (2); but it may be recalled to mind that the surface of the Older Volcanic rock is about 190 feet above the level of the stream, which has a fairly rapid fall. The limestone and sands overlying the Older Volcanic rock may be traced continuously for four miles to the southward, when we reach the quarry opposite the Clyde School (2, p. 183). Here the surface of the volcanic rock has dropped to about 40 feet above the level of the stream, in spite of the rapid fall of the latter. The Upper Maude limestone is now overlain by fossiliferous clays, into which it passes upwards, the fossils from the clays showing, as we have previously pointed out, the closest agreement with those of the clays associated with the Batesford limestone. About a mile and a half further down the stream we recently noted the most southerly outcrop of the Eocene basalt, namely in Section IV., Allotment B, Parish of Darriwill. The following section is displayed on the left bank. From the water's edge up to 40 feet is a very vesicular and rubbly decomposed basalt. On this rests the Eocene rock. Fragments of polyzoal rock were found, as well as brown sandy limestone. Then occurs a stretch of level ground which runs back from the river to an escarpment of Newer Volcanic rock, which flanks the Maude tableland. There is no clear exposure of the Eocene rock in the section, but it is visible a quarter of a mile below under the Newer Volcanic rock, dropping rapidly to the southwards, as seen in the long cliff section. There is, as mentioned, no actual exposure of the Older Volcanic rock south of this, and judging by the soil and surface contour we think it comes to the river level near the house in Section IV., Allotment E (Calleray's). The slopes about here are composed of the marine series with the usual capping of Newer Volcanic rock. About half a mile south of Calleray's there is an exposure of Eocene in the river bed at the foot of a steep cliff. On the opposite (right) bank of the stream a long escarpment runs east and west, and the almost horizontal lines of stratification, as shown by the earthy limestone bands, are a marked feature in the landscape. From a road-cutting along the foot of this hill, about a couple of hundred yards above Moodie's homestead, we gathered a few fossils.

Brachiopoda.
  Terebratula vitreoides, T. Woods.
Lamellibranchiata.
  Ostrea sp.
  Pecten murrayanus, Tate.
  Lima linguliformis, Tate.
  Leda vagans, Tate.
  Nucula tenisoni, Pritchard.
  Limopsis belcheri, Adams and Reeve.
  Pectunculus laticostatus, Quoy and Gaimard.
  Plagiarca cainozoica, Tate.
  Corbula pyxidata, Tate.
Gastropoda.
  Tenagodes occlusus, T. Woods.
  Emarginula sp.

Scaphopoda.

Dentalium aratum, Tate.
Entalis mantelli, Zittel.
,, subfissura, Tate.

Half a mile below, a similar road-cutting near Baker's gave us another opportunity of seeing the nature of the beds clearly. The valley hereabouts is of less depth than almost anywhere else, being only about eighty feet deep. The marine beds are about sixty feet thick, and pass up from grey sandy marls into more sandy beds with bands of hard, ringing, concretionary limestone, and towards the top become more ferruginous. The face of the section is sparsely strewn with small quartz pebbles, but we could not find any bed from which they might be derived. The remaining twenty feet of the hill consists of the usual volcanic capping, the rock being a rather coarse dolerite, judging by hand specimens. Fossils were only obtained from the lower part of the section, are not very common, and are of Eocene age.

BAKER'S ROAD-CUTTING.

Foraminifera.

Zoantharia.

Flabellum victoriæ, Duncan.
Conosmilia anomala ?, Duncan.

Echinodermata (Cidaroid spines).

Polyzoa.

Lamellibranchiata.

Dimya dissimilis, Tate.
Pecten zitteli, Hutton.
Meleagrina crassicardia ?, Tate.
Barbatia celleporacea, Tate.
Leda vagans, Tate.
Trigonia tubulifera, Tate.
Crassatella communis, Tate.
Cardita polynema, Tate.
Cytherea eburnea, Tate.
Myochama trapezia, Pritchard.

Gastropoda.

Ranella prattii, T. Woods.
Genotia angustifrons, Tate.

Pleurotoma sp.
Thylacodes conohelix, T. Woods.

Scaphopoda.
Dentalium aratum, Tate.
Entalis subfissura, Tate.
,, mantelli, Zittel.

Pisces (otoliths).

About a mile to the south of this, on the road which runs south from Baker's Bridge, is a small cutting in yellow calcareous sandstone, with very hard bands of limestone. This proved a difficult bed to work for fossils, as they were very scarce, and when found consisted only of hollow casts. The nature of the rock, however, was such that the imprint of the ornament was beautifully sharp, and there was very little difficulty in recognising the greater number of the specimens as soon as they were exposed by the hammer.

GHERINGHAP.

Foraminifera.

Crustacea (crab chela).

Polyzoa.

Brachiopoda.
Terebratulina scoulari ?, Tate.

Lamellibranchiata.
Lima bassii, T. Woods.
Chione cainozoica, T. Woods.
Cardita delicatula, Tate.
Chama lamellifera, T. Woods.

Gastropoda.
Mitra ligata ?, Tate.
Scalaria sp.
Turritella tristira, Tate.
,, acricula, var., Tate.
,, platyspira, T. Woods.
Rissoa sp.

Scaphopoda.
Dentalium aratum, Tate.
Entalis mantelli, Zittel.

As a few hundred yards below this cutting there is a long outcrop of limestone marked on the Quarter-sheet, 24 N.E., the boundary of which we were now approaching, it was very necessary that clear evidence as to its age should be obtained. This strip of limestone is shown on the map as immediately underlying the Pliocene beds, which are mapped as very thick from here to the viaduct, and though the outcrop is clearly enough shown on the map, yet there was but one small exposure in an old disused quarry, the extent of the bed being indicated by the numerous scattered fragments of limestone at the foot of the escarpment. Owing to the unfortunate system of representing all limestones by a blue colour on the quarter-sheets, no hint of the age of the bed is given, and it is merely shown to underlie the Pliocene deposit. In the outcrop at the quarry we could find no identifiable fossils, a few fragmentary polyzoa and foraminifera being all that we saw. There can, however, be no doubt whatever that the outcrop is part of the same bed as is exposed in the road-cutting just mentioned, and it must consequently be referred to Eocene age.

To the north of this the river skirts the southern boundary of a small area of granite, as shown on the Quarter-sheet. South of the confluence of Sutherland's Creek, which skirts the granite area on its eastern border, a small exposure of limestone is mapped, and is represented as intercalated in Pliocene beds. At the locality indicated we found numerous boulders of white, hard, magnesian limestone strewn about near the foot of the slope, but it appeared not to be fossiliferous, and its original position is not clear. We found none *in situ*, and it may be merely a decomposition product from the overlying volcanic rock, and perhaps owes its present position to its having rolled down the face of the escarpment. To the south-west of this point, owing to the removal of the volcanic rock by denudation over about a square mile of country, a series of beds are brought to view which are mapped as "Older Pliocene." In their upper part they pass under the edges of the basalt plateau, and a couple of railway cuttings through small basaltic outliers show the relationship of the two sets of beds very clearly. The basalt cap, as shown in the cuttings, is very thin, nowhere exceeding twenty feet in thickness, and thins out to nothing at the two ends of each of the cuttings. Under the basalt comes a deposit of ferruginous sandstone bands, sands and gravels, at times passing irregularly into white sands, with here and there a few nodules of hard quartzite just below the volcanic rock. The texture varies from exceedingly fine, well-rounded sands to light gravel, and a prolonged search for fossils in these cuttings showed, as is so often the case in rocks of this character, that organic remains are few and far between ; in fact, all we found was the imprint of a single leaf, showing probably the fresh-water nature of the deposit. On the northern slopes towards the river, and at a lower level than these beds, the Quarter-sheet notes "Ironstone full of fossils." These fossiliferous beds are exposed in an old road-cutting leading down to the river, but fossils are more plentiful in the loose blocks which thickly strew the slopes below. The deposit is of especial interest, as the beds prove to be of Miocene age.

MOORABOOL VIADUCT.

Miocene Fossils.

Lamellibranchiata.

Placunanomia ione, Gray.
Modiola sp.
Leda woodsi, Tate.
Leda sp.
Nucula tenisoni, Pritchard.
Trigonia acuticostata, McCoy.
Chione subroborata, Tate.
Cytherea submultistriata, Tate.
Mactra hamiltonensis ?, Tate.
Myadora corrugata, Tate.
,, brevis, Sowerby.
Corbula ephamilla, Tate.
Barnea tiara, Tate.

Gastropoda.

Phos tuberculatus, Tate.
Nassa sublirella, Tate.
,, crassigranosa, Tate.
Cancellaria wannonensis, Tate.

Pelicaria coronata, Tate.
Natica varians, Tate.
Turritella sp.
Lampania sp.
Bankivia sp.

The whole of the above twenty-two species are obtained in Miocene deposits elsewhere, whereas only five are recorded as ranging into the Eocene.

Of the above twenty-two species seventeen have been specifically named, including one doubtful identification; the remainder are as yet undescribed species.

The seventeen described species occur elsewhere as follows:—

Muddy Creek Miocene - -	17 (1 doubtful).
Jemmy's Point Miocene - -	17 ,,
Beaumaris Miocene - - -	13

The Quarter-sheet bears the same colour from the top of the hill down to the river flat, the whole series being referred to Older Pliocene. Towards the foot of the hill, however, the character of the beds changes, and, though we found no fossils, it is probable that the lower part of the beds is Eocene, as fossiliferous beds of this age occur less than half a mile lower down the stream and are in their upper part of similar lithological character.

The presence of marine Miocene beds here, where they are so clearly overlain by volcanic rock, is of importance when viewed in connection with a deposit recently described by Messrs. J. Dennant and J. F. Mulder at Shelford, about eighteen miles to the westward of the present locality (3). Finding the marine Miocene beds resting on basalt, and basalt also occurring further from the river, and at a higher level, these authors have assumed that the two basaltic outcrops belong to the same period and practically to the same flow. Arguing from these premises they state their view to be that the basalt forming this portion of the Western Plains is not younger than Miocene, and they ascribe the presence of the marine Miocene beds in that locality to a submergence after the gorge had been partly cut out by the stream. An examination of the section which they give, however, shows that a different interpretation may be placed on their observations, namely, that there are really two basalts of distinct ages present and separated by marine beds. The fact that, at the Moorabool locality, the basalt overlies the Miocene beds is certainly strong presumptive evidence that the relative position to which Messrs. Etheridge and Murray referred the newest of the basalts of the Shelford district is the correct one, namely, that it is subsequent to the beds which the Survey termed Older Pliocene, and which are now generally called Miocene. Messrs. Dennant and Mulder state that, in the section in which they found the Miocene deposit, the base of the volcanic rock is hidden by the recent river alluvium. If then, as appears probable, there be two basalts at Shelford, the age of the lower one is still undetermined. It must be pre-Miocene, and from its close proximity to the Eocene basalt of Maude, it will quite possibly be found to be a part of the same flow.

The railway cutting on the left bank of the stream shows, under a thin basalt capping, beds of the same character as those described above on the right bank, and yielded no fossils. Eastwards from the Moorabool Railway Station the railway runs in the valley of Cowie's Creek, and several cuttings show the beds beneath the basalt capping, and they are also displayed in natural sections in the valley. Daintree and Wilkinson, who mapped the Quarter-sheet, 24 N.E., indicate two sets of beds as occurring, namely, "Older Pliocene" and "Miocene," or, as we consider them, Miocene and Eocene. Judged by the light of the section above described to the west of the viaduct, it is possible that this is correct, as the levels are about the same. The beds merely differ in the fact that these to the eastward are not highly ferruginous. They are sandy, sometimes calcareous, and in places in immediate contact with the overlying basalt are changed to quartzites. The dip is slight and is at first north-westerly, whereas further east, where the age is shown to be Eocene by the fossils, the dip is reversed, being to the south-east. These are only apparent dips, as shown in the railway cutting. About four miles to the northward a small patch of Miocene (? Eocene) is mapped (this outcrop is uncoloured in some copies of the Quarter-sheet, but is coloured Miocene in others), and an anticline with a north-east strike is shown. The axis of the anticline would run, if produced in a straight line, near to this locality.

The evidence, then, as to whether we have here an anticline in Eocene strata merely, or an unconformable junction between easterly dipping Eocene and westerly dipping Miocene is fairly evenly balanced, and we leave the question open. At the locality marked as fossiliferous on the Quarter-sheet (Section 104) we found fossils in the railway cutting and also close to the creek bed which showed the Eocene age of the deposit. The upper beds yield very few forms, but those at the lower level are fairly rich, though the fossils are very much decomposed.

RAILWAY-CUTTING.

Foraminifera.
Cidaroid spines.
Crustacea (crab carapace).
Polyzoa.
Brachiopoda.
    Waldheimia insolita ?, Tate.
    Terebratulina scoulari, Tate.
Lamellibranchiata.
    Ostrea sp.
    Pecten sp.
    Limatula jeffreysiana ?, Tate.
    Spondylus pseudoradula, McCoy.
    Dimya dissimilis, Tate.

COWIE'S CREEK.

Brachiopoda.
    Terebratulina scoulari, Tate.
Lamellibranchiata.
    Pecten zitteli, Hutton.
    Leda vagans, Tate.
    ,, apiculata, Tate.
    ,, huttoni, T. Woods.
    Limopsis belcheri, Adams and Reeve.
    Plagiarca cainozoica, Tate.
    Cardita polynema, Tate.
    ,, delicatula, Tate.
    Diplodonta subquadrata, Tate.
    Cytherea eburnea, Tate.

Pholadomya australica, Tate.
Cuspidaria subrostrata, Tate.

Gastropoda.

Cypræa leptorhyncha, McCoy.
Cassidaria gradata, Tate.
Natica hamiltonensis, T. Woods.
Turritella sp.
Tenagodes sp.
Cerithium apheles, T. Woods.
Tinostoma parvula, T. Woods.
Emarginula sp.
Cylichna sp.

Scaphopoda.

Dentalium aratum, Tate.
Entalis mantelli, Zittel.
,, subfissura, Tate.

With the exeception of the section noticed by us in a previous paper (1), there does not appear to be any fossiliferous exposure of Eocene rocks between the viaduct and the limestones below Batesford. In the same paper we described the nature of the beds displayed in the river sections between Hope's Mill-dam and Fyansford, and subsequently again referred to the section displayed at M'Cann's Filter Quarries (2, p. 193), and gave a list of fossils from the clays of the section (4, p. 161).

The question of the difference of level of the lava on the two sides of the Moorabool, between Batesford and Fyansford, we alluded to in a previous paper (1). It seems probable that the lava to the west, occupying the lower level, is younger than that capping Orphanage Hill, the latter being a southerly extension of that capping the Miocene beds near the viaduct. This suggestion would, of course, imply great denudation over a considerable area after the effusion of the Orphanage Hill lava. From a careful examination of the district we do not think that it can be due to faulting, although faulted marine tertiaries occur at no great distance, namely at Waurn Ponds and at Curlewis. At the former place the limestone at M'Cann's old quarry is cut off to the southward by a vertical fault, the amount and direction of the displacement not being known, and the quarry is abandoned, while the slight series of step faults at Curlewis we have described elsewhere.

SUMMARY.

The long series of sections displayed in the valley of the Moorabool shows very clearly the sequence of our Eocene rocks. The general dip is in the direction of the stream, and at a more rapid rate than the fall of the valley, so that the beds disappear in regular order as we go southwards. The Upper Marine Series near Maude, classed as Upper Miocene by the Survey, is seen to pass beneath clays which are the near representatives of, if not absolutely identical with, those of Orphanage Hill, Fyansford, which have been referred by the Survey to the Oligocene. and by us to the Eocene. These beds extend in the valley from near the Maude bridge, with perhaps a short break near the junction of Sutherland's Creek, to the Barwon. Near the viaduct they are overlain by marine and freshwater Miocene beds, which are in turn capped by the lava flow of the plains.

Beneath the Upper Maude beds is seen the Older Volcanic, extending from near the confluence of the Coole Barghurk Creek for about ten miles down stream, when it disappears beneath river level. Under the Older Volcanic sheet, and between it and the Ordovician, is a series of beds which to the northward is of freshwater origin and contains plant remains—the "Miocene gravels" of Selwyn. At about two miles above Maude they contain a marine fauna in their upper portion, and they dip below river level some three miles below this point. This fauna we have previously correlated with that of Spring Creek.

A tongue of the Anakie granite, as shown by numerous outcrops, extends down Sutherland's Creek, through the Dog Rocks, and reaches as far to the southward as the north-western border of the Barrabool Hills. At the Dog Rocks and at the Barrabool Hills gabbro is associated with it. The relations of the two rocks are being, we understand, worked out by Mr. E. G. Hogg. Here, as elsewhere in Victoria, the granite is probably Post-Silurian, and intrudes the graptolite-bearing Ordovician, which is extensively exposed in the northern parts of the area treated of.

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